CORRELATION OF RISK FACTORS WITH CARIES PREVALENCE AMONG U.S. MILITARY RECRUITS

by

Blake M. Rosacker
LT, DC, USN

A thesis submitted to the Faculty of the
Comprehensive Dentistry Graduate Program
Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
in partial fulfillment of the requirements for the degree of
Master of Science
in Oral Biology

June 2012

Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
Bethesda, Maryland

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Blake M. Rosacker

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Oral Biology at the June 2012 graduation.

Thesis Committee:

Kim E. Diefenderfer, DMD, MS, MS
CAPT, DC, USN
Thesis Supervisor

Joseph D. Molinaro, DMD, MS
CDR, DC, USN
Graduate Program Director, Comprehensive Dentistry

Thomas M. Leiendecker, DDS, MPH
CAPT, DC, USN
Director, Tri-Service Center for Oral Health Studies
Uniformed Services University of the Health Sciences

Glen A. Munro, DDS, MS
CAPT, DC, USN
Dean, Naval Postgraduate Dental School

NAVAL POSTGRADUATE DENTAL SCHOOL
Blake M. Rosacker

2012

ABSTRACT

CORRELATION OF RISK FACTORS WITH CARIES PREVALENCE
AMONG U.S. MILITARY RECRUITS

BLAKE M. ROSACKER
MASTER OF SCIENCE, COMPREHENSIVE DENTISTRY, 2012

Thesis directed by: KIM E. DIEFENDERFER, DMD, MS, MS
CAPT, DC, USN
PROFFESSOR, DENTAL RESEARCH
NAVAL POSTGRADUATE DENTAL SCHOOL

Introduction: Epidemiologic research suggests that 60% of dental caries occurs in 20% of the population. Compared to the general population, U.S. military recruits represent a unique subgroup that exhibits multiple characteristics associated with increased caries risk. Identifying specific factors associated with high (and low) caries risk would facilitate a more refined approach to individualized patient care, greater therapeutic benefit, and improved economic efficiency in the delivery of dental services.

Objectives: To determine if dental caries prevalence among U.S. military recruits correlates with the following factors: gender; race; age; tobacco use; periodontal status; dietary habits; oral hygiene practices; prior dental history; and education level.

Methods: This study evaluated data collected during the 2008 Recruit Oral Health Survey administered by the Tri-Service Center for Oral Health Studies (TSCOHS). Survey questionnaires completed by 5,835 recruits (1,132 U.S. Navy, 1,217 U.S. Marine Corps, 1,928 U.S. Army, 1,558 U.S. Air Force) were analyzed to determine correlations between dental caries prevalence and specific socio-demographic, clinical, and behavioral factors. Data were analyzed using stepwise linear regression ($\alpha = 0.05$).

Results: Several behaviors are significantly associated with caries experience. Linear regression revealed the strongest predictive model includes: smoking($p < 0.0001$), drinking regular soda between meals ($p < 0.0001$), not seeing a dentist regularly($p < 0.0001$), frequency of tooth brushing ($p < 0.005$), sugary snacks between meals ($p < 0.006$), and using smokeless tobacco ($p < 0.017$)

Conclusions: Based on self-reported answers to a 37-item questionnaire, several behaviors showed a positive relationship to caries prevalence. Strongest behavioral links included: using tobacco products, drinking regular soda and consuming sugary snacks between meals, and not visiting the dentist regularly. Therefore, it would seem wise to offer diet counseling and encourage tobacco cessation to our military personnel.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1.	DMFS	The number of decayed, missing, and filled surfaces (adult)
2.	DMFT	The number of decayed, missing, and filled teeth (adult)
3.	NHANES	National Health and Nutrition Examination Survey
4.	TSCOHS	Tri-Service Center for Oral Health Studies
5.	ODRM	Oral Disease Risk Management
6.	PSR	Periodontal Screening and Recording
7.	ECC	Early childhood caries
8.	HEI	Healthy Eating Index
9.	dfs	the number of decayed and filled surfaces (child)

CHAPTER 1: REVIEW OF LITERATURE

The ability to positively predict the incidence of dental caries in individuals has been a topic of research in the dental community for a long time. If an accurate caries predictive model existed, it would allow for a more refined approach to customized patient care and a more efficient delivery of dental services.

Many leaders in dentistry today, along with the curricula taught in many dental schools, advocate that dental practitioners establish a patient's risk of developing dental caries in order to create an appropriate level of risk management and treatment. This philosophy is derived from findings that indicate the prevalence of dental caries has decreased overall since 1971 (Brown, Wall & Lazar, 2002; U.S. Public Health Service, 1989), and that 60% of caries lesions in school children occur in only 20% of the population (U.S. Public Health Service, 1989; Powell, 1998; Stamm, 1991). However, the changing patterns in caries experience evident over the past three decades make it clear that certain subsets of the population have an increased risk for developing new caries lesions (Brown & colleagues, 2002, Disney and colleagues 1992).

EPIDEMIOLOGY OF DENTAL CARIES

Beginning in the early 1970s and continuing through the mid-1990s, several major epidemiologic studies described trends in dental caries experience among children and adults in the U.S. The first National Health and Nutrition Examination Survey (NHANES I) was conducted from April 1971 through June 1974 with a nationwide probability sample of approximately 28,000 people, aged 1 to 74 years, from the civilian, non-institutionalized population of the contiguous United States, excluding people living

on American Indian reservations. This survey served as the baseline for comparison with all subsequent investigations. The National Dental Caries Prevalence Survey (1979 – 1980) reported that mean DMFS scores among children aged 5 to 17 were 32% lower than in NHANES I; this reduction occurred at every age and in all regions of the U.S. (US Public Health Service, 1981). The National Survey of Dental Caries in U.S. School Children (1986 – 1987) found that the mean DMFS scores among 5- to 17-year-olds had declined an additional 36%, from 4.77 per child in 1980 to 3.07 per child in 1987. In 1980, 37% of all children (5 to 17 years old) had no caries in their permanent teeth. By 1987, the proportion of children who were caries-free in their permanent dentition had increased to nearly 50% (US Public Health Service, 1989; Brunelle and Carlos, 1990). Similarly, the National Survey of Oral Health of U.S. Employed Adults and Seniors (1985 – 1986) found only 4.2 % of persons under age 65 were edentulous, however the survey excluded the unemployed, persons in agriculture and mining.(US Public Health Service, 1987)

NHANES III was conducted from October 1988 through October 1994 with a nationwide probability sample of 39,695 people, two months of age or older, from the civilian, non-institutionalized U.S. population in the 50 states and the District of Columbia. African-Americans, Mexican-Americans, children 2 months to 5 years of age, and adults 60 years of age and older were over-sampled to obtain statistically reliable estimates for these populations. Results from the NHANES surveys demonstrated a decrease in caries prevalence by 27% from 1971 to 1994 among adults between the ages of 18 to 45 years. The decrease was greater among white adults (28%) than among black adults (21%). The decline was greatest among 18- to 25-year-olds (44%). Among those

aged 26 to 35 years, the mean decrease was 39 percent, and for those aged 36 to 45 years, the mean decrease was 21 percent. Overall, combining all age groups and ethnicities surveyed, caries experience among U.S. adults decreased by 11 percent from NHANES I to NHANES III (NHANES II, conducted from 1976 to 1980, did not include an oral health component). Similar findings were noted among children. Among children between the ages of 6 and 18 years, the number of decayed, missing and filled permanent teeth (DMFT) decreased from 4.44, as measured by NHANES I, to 1.90, as measured by NHANES III. This decline has been attributed to the widespread fluoridation of public water supplies and the wider utilization of preventive dentistry services (Brown & colleagues; U.S. Public Health Service, 1989, U.S. Public Health Service, 1989). The NHANES studies are ongoing, and along with other recent studies, data suggest that the decline in caries experience may be slowing, or actually reversing among some demographic groups (Beltran-Aguilar & colleagues 2005). Overall, the oral health status of Americans, as measured by Healthy People 2010, improved slightly or remained unchanged between 1988-1994 and 1999-2004 (Dye & colleagues, 2010; Dye & Thornton-Evans, 2010).

CARIES RISK FACTORS

Despite the multi-factorial etiology of dental caries, early studies focused primarily on single risk factors or combinations of a few variables. Most research concentrated on G.V. Black's classic caries etiology model of host, microflora, and diet (Newbrun & Leverett, 1990).

Dietary Habits. The Stephan Curve is characterized by an immediate, rapid drop in plaque pH when a patient is exposed to an oral glucose solution which is attained

within a very few minutes. This is followed by a slower rise taking anywhere from 15 to 40 minutes until the resting pH is attained. The time course varies between individuals, and the nature of the challenge (Stephan 1940). Specifically, patients with active caries have a lower resting pH level in their oral cavity, experience a greater overall drop in pH when exposed to an oral glucose solution, and the duration of time required to return to resting levels is increased.

The seminal study linking consumption of sugars to dental caries was conducted by Gustaffson and colleagues in Vipeholm, Sweden from 1945 through 1952 (Gustaffson & colleagues, 1954; Krasse, 2001). The study was conducted in a mental institution and, due to present-day ethical considerations, is unlikely to be repeated today. Patients were divided into groups with controlled consumption of sugars that varied in frequency, amount, form, and whether they were consumed between meals. The two extremes of the study included one group that consumed no added sugar whatsoever and another group that consumed up to 24 sticky toffees daily between meals. The results revealed several important findings that we still espouse today: (1) sugar consumption increased caries activity; (2) caries activity was greater if the sugar was in a sticky form; (3) caries experience was greatest if the sugar was taken between meals and in a sticky form; (4) the increase in caries experience under uniform conditions showed great individual variation; and (5) caries experience declined upon withdrawal of sticky foodstuffs from the diet (Burt & Eklund, 1988). However, more recent research has called into question these long-held beliefs. Dietary surveys of both children and adults have failed to demonstrate such clear associations between dietary sugar consumption and caries experience. Rather, these studies suggest that sugar consumption may not increase caries

experience for most individuals, but may pose a significant threat for those already susceptible or predisposed to caries (Rugg-Gunn &colleagues, 1984; Burt &colleagues, 1988; Beighton, Adamson, & Rugg-Gunn, 1996; Burt & Pai, 2001).

Microbiological Factors. Mutans streptococci and lactobacilli have been specifically linked to the initiation and progression of caries. However, the direct association between bacterial counts and caries incidence is found more so in groups, rather than in any one individual (Krasse 2001). In general, when salivary mutans streptococci exceeds 2x10^5/ml the individual is at risk for dental caries (Beighton and colleagues, 1996). Bacterial counts are still useful, but unfortunately are not a definitive test for caries risk.

Oral Hygiene. It has often been hypothesized that the effective removal of plaque through oral hygiene would correlate to a significant decrease in caries incidence; however, individual oral hygiene status is poorly related to caries experience. Instead, individual oral hygiene has a much larger effect on periodontal health than caries experience. In terms of caries prevention, the main purpose of regular tooth brushing is to introduce fluoride into the mouth at regular intervals via the toothpaste (Burt and Eklund 1992).

Salivary Factors. Saliva performs multiple functions for the protection of teeth from the development of caries. In general it allows for the mechanical washing away of food, offers buffering capacity, and contains multiple antibacterial factors. Saliva also aids in other functions such as chewing, swallowing, speaking, and digestion. It has been shown in multiple studies that the total lack of saliva results in rampant caries in a few months. This finding has led to research trying to identify specific salivary components

that are more related to caries development, however, as of yet no correlation can be made between specific salivary component levels and caries activity (Larmas 1992). A major problem in studying elements of saliva is that salivary composition varies with flow rate, duration of stimulation, plasma composition, and time of day at which samples are collected (Newbrun 1989). In general, saliva plays an extremely important role in attenuating caries; however isolating the exact constituent levels for this capacity remains elusive.

CARIES RISK PREDICTION

A common shortcoming of the early caries prediction studies was that they demonstrated only associations between risk factors and the prevalence of dental caries. Because they lacked prospective designs, these studies could not determine causality and, therefore, could not identify factors as true predictors of disease incidence (Beck, 1990). As research in this area has continued, it has become apparent that single point variables can not accurately and reliably predict future caries risk.

The University of North Carolina Caries Risk Assessment Study, conducted from 1986 to 1989, evaluated baseline caries predictors such as salivary microbiological tests, socio-demographic factors (e.g., family income), and dental behaviors (e.g., brushing frequency) among 4,117 children (ages 5 to 10). The research revealed that clinical variables, such as prior DMFS and pit and fissure morphology, were stronger predictors of future caries experience than were non-clinical variables; past caries experience was the most significant predictor of future caries experience. Other important variables were fluoride exposure, socioeconomic status, tooth morphology, and presence of destructive microflora, such as *Streptococcus mutans* and lactobacilli (Newbrun & Leverett, 1990;

Graves & colleagues, 1991). Leverett and colleagues (1993) sought to create a caries prediction model in 6 year old children from both fluoridated and non fluoridated communities. Analyzing 472 caries free children, the authors were able to positively predict which patients would develop caries within 6 to 12 months with an accuracy of 82.8% and able to accurately predict who would not with an accuracy of 82.4%. In the fluoridated community the parameters used for prediction were: numbers of lactobacilli and mutans streptococci in saliva, salivary fluoride concentration, plaque index, length of time bottle fed, and age at which fluoride dentrifice use began. In the fluoride deficient community the parameters used for prediction were: numbers of lactobacilli and mutans streptococci in saliva, salivary fluoride concentration, plaque index, length of time bottle fed, and use of dietary fluoride supplements. There are, however, limitations to this prediction model. The authors admit that it would be quite difficult for a practicing dentist to carry out microbiological analyses effectively and efficiently, and to conduct chemical analyses for calcium, phosphate, and fluoride with the precision needed (Leverett and colleagues, 1993).

Steiner, Helfenstein, and Marthaler (1992) investigated as many as 46 variables in children ages 7 to 8 and 10 to 11 for their association with 4-year caries increment. However, prediction models utilizing just three variables (sound primary molars, discolored pits and fissures of permanent molars, and white spots on smooth surfaces of first permanent molars) were nearly as powerful as multivariate prediction models and were superior to using DMFT scores alone. Moreover, using only the single variable of dmft scores in younger children had almost the same predictive power as multivariate models.

More recent studies have focused on multiple variable modalities to achieve higher accuracy in caries prediction. For example, using data obtained from the NHANES III (1988 – 1994), Sohn, Burt and Sowers (2006) used a multivariate logistic regression model to analyze fluid intake of 5,985 children, ages 2 to 10 years. They found that a high consumption (> 30% of total daily fluid intake, or approximately 500 ml/day) of carbonated soft drinks increased the risk of caries in the primary dentition by 50%, as compared to high consumption of juice, and by nearly 200%, as compared to high consumption of milk or water. Carbonated soft drink consumption varied by age, gender, race, and socioeconomic status. Soft drink consumption was slightly more prevalent among boys than girls, and among older children (ages 6 to 10); white children, as well as those of higher income, tended to report higher soft drink consumption. These children had significantly higher dfs scores; only 52% were caries-free, while 62% - 66% of children with high water, high juice, or high milk consumption were caries-free. Similarly, also using data from NHANES III, Nunn and colleagues (2009) evaluated the relationship of early childhood caries (ECC) to eating habits and socio-demographic variables. Eating habits were scored according to the Healthy Eating Index (HEI), a ten-component measure of overall diet quality, developed by the U.S. Department of Agriculture, based on the level of compliance with the daily serving recommendations of the Food Guide Pyramid (Kennedy & colleagues, 1995). Nunn and colleagues reported that 2- to 5-year-old children with the highest HEI were 44% less likely to exhibit ECC than those with the lowest HEI. Although race/ethnicity and income were associated with ECC, multivariate logistic regression analyses revealed that the HEI was a strong predictor of severe ECC, independent of race/ethnicity or income.

SENSITIVITY AND SPECIFICITY OF PREDICTION MODELS

In general, most caries risk models are better at predicting who will not develop new caries as opposed to identifying those who will (Powell 1998). This is a concept related to sensitivity and specificity. The sensitivity of a test measures the proportion of actual positives which are correctly identified as such (e.g. the percentage of sick people who are correctly identified as being sick), while specificity measure the proportion of negatives which are correctly identified (e.g. the percentage of healthy people who are correctly identified as not being sick).

Diagnostic Test Result	Actual Condition	
	Positive	Negative
Positive	True Positive (A)	False Positive (B)
Negative	False Negative (C)	True Negative (D)

Sensitivity = A / (A + C) Positive Predictive Value = A / (A + B)

Specificity = D / (B + D) Negative Predictive Value = D / (C + D)

PPV: "the proportion of subjects with positive test results who are correctly diagnosed. It is a critical measure of the performance of a diagnostic method, as it reflects the probability that a positive test reflects the underlying condition being tested for."

NPV: "the proportion of subjects with a negative test result who are correctly diagnosed. A high NPV means that when the test yields a negative result, it is uncommon that the result should have been positive."

Snyder (1951) proposed that a suitable predictive test should possess the following characteristics:

1. Maximal correlation with the clinical status of the patient.
2. Maximal correlation with caries increment.

3. Accurate reproducibility of results.
4. Ease of performance, requiring little technical skill.
5. Inexpensive procedures and equipment.
6. Achievement of rapid results.
7. Measurement of factors in the caries process.

In addition, it would be advantageous to have a predictive model that was not predicated on previous caries experience, but instead was helpful in identifying caries risk prior to loss of tooth structure. However, because of the complex and multi-factorial nature of dental caries, it may be very difficult, if not impossible, to meet all of the requirements for an ideal caries predictive model (Powell, 1998b; Hausen, 2003).

Through dental research, the variables that have been found to be most predictive of future caries experience are: past caries experience, dietary sugar/carbohydrate consumption, fluoride exposure, salivary levels of *Streptococcus mutans* and lactobacilli, age, socioeconomic status, education level, and salivary flow. In addition, Powell (1998b) has described that the status of the most recently erupted or exposed tooth surface has become the best predictor of caries for the newly emerging surfaces. For example, caries in primary incisors could be used as a predictor for caries in primary molars.

AGE- SPECIFIC CARIES PREDICTION MODELS

Caries prediction is a complex process that is multifactorial in nature and contains many different variables. In addition, certain variables may be predictive for one age population but may not be predictive for others. These populations are typically grouped into several categories: children (2-12), teens (13-17), adults (18-65), and geriatric

patients (older than 65). Caries predictive variables may be quite consistent within an age group, but may differ significantly from one age group to another (Powell 1998b; Ettinger, 1999). As an example, a model for predicting caries rates in a geriatric population might include exposed root surfaces and xerostomia-inducing medications; this particular model, however, would not be useful in a population of children (Powell 1998b). In addition, the presence or absence of sealants may be an important factor for children, but not necessarily for older adults or geriatric patients. Younger adults may exhibit still other predictors. Roberts-Thompson and Stewart (2008) conducted dental examinations on 644 South Australian young adults 20-25 years old. The mean number of decayed, missing, or filled tooth surfaces (DMFS) was 6.05, with untreated cavitated decayed surfaces (DS) evident in 28.6 percent of the patients. The best predictive variables for higher caries rates included: (1) being on government assistance; (2) being unemployed; (3) visiting a dentist only when a problem arises; (4) drinking 5+ acidic drinks a day; and (5) smoking.

At present, because of the many factors that must be considered in model development, no single predictive model can be universally recommended for clinical use for all patient populations. However, models that are specific to certain sub-populations may prove to be more practicable, and may be especially valuable for populations that are unique from the rest of society.

CLINICIANS' ABILITIES TO ASSESS CARIES RISK

Rather than using a formal predictive model, clinicians often make assessments of their patients' caries risk based on their intuition and clinical experience. The University of North Carolina Caries Risk Assessment Study sought to evaluate clinicians' abilities to predict futures caries incidence. The four-year study involved over 4000 school children in grades 1 and 5 and included four dentists and two hygienists who were given a four-hour training session in order to achieve a level of calibration on clinical criteria. The results indicated that examiners' subjective assessments of caries risk status did, indeed, have strong predictive value. For the four dentists who participated as patient examiners in the study, individual sensitivities ranged from 0.62 to 0.72, while specificities ranged from 0.85 to 0.91. Ultimately, the goal is to have specificities at or above 0.85 and sensitivities at or above 0.75. While this study showed adequate specificity range, the sensitivity levels were slightly lower than desired (Disney and colleagues, 1992).

However, Alanen and colleagues (1994) evaluated the abilities of 52 dentists and 25 hygienists to predict one-year caries increments in 5- to 16-year old children, and found that there were a large number of false negative classifications. The mean sensitivity and specificity were 0.44 and 0.90 respectively, with dentists (sensitivity 0.45, specificity 0.91) having slightly better prediction rates than hygienists (sensitivity 0.33, specificity 0.88). Examiner characteristics (e.g., years or types of training, years of practice) were not presented; therefore, conclusions regarding reasons for the observed differences in predictive abilities were not possible.

CARIES MANAGEMENT BY RISK ASSESSMENT (CAMBRA)

At any given time, the balance of caries development can be tipped toward caries progression and demineralization or toward repair via remineralization. The eventual outcome will determine whether an individual tooth surface becomes cavitated. This particular concept forms the basis for risk assessment and for caries management based upon risk assessment (Featherstone and colleagues 2002). This caries balance model for disease has led to the development of a caries risk form, which is used to evaluate a patient's individual risk and identify specific risk factors. Using a standardized risk assessment form can help in the effort to consistently identify caries risk factors for each patient and then employ the appropriate treatment. In the case of low caries levels, remineralization procedures may be enough to halt decay; however, in the case of caries active individuals, antibacterial therapy may be needed in conjunction with fluoride therapy (Featherstone and colleagues 2002). The difficulty in this approach is trying to accurately assess its efficacy for reducing caries and determining if its preventive measures are effective. No real conclusive research exists to definitively demonstrate CAMBRA's effectiveness.

DENTAL CARIES EXPERIENCE IN THE U.S. MILITARY

The U.S. Department of Defense (DoD) places a high priority on the health of its service members. U.S. military dental services utilize the DoD Oral Health and Readiness Classification System (HA Policy 02-011) to identify varying degrees of dental health and readiness among military personnel. The dental readiness of personnel for deployment is determined by the severity of dental conditions and the requirement for

urgent dental treatment. The DoD Oral Health and Readiness Classification System is divided into four categories as listed in Table 1.

Table 1. Department of Defense Oral Health and Readiness Classification System.*

Dental Classification	Examination Status	Dental Treatment Need	Deployment Status
Class 1	Current (not > 13 months)	None	Deployable
Class 2	Current (< 13 months)	Non-urgent	Deployable
Class 3	Current (< 13 months)	Urgent	Not deployable
Class 4	Expired (> 13 months)or Unknown	Unknown	Not deployable

* Department of Defense: Individual Medical Readiness. Washington, DC, DoD, January 3, 2006.

In 1994, 2000, and 2008, the Tri-Service Center for Oral Health Studies (TSCOHS) administered oral health surveys to U.S. Air Force, Army, Marine Corps, and Navy enlisted recruits at the time of their entry into active duty service. The surveys collected data on oral health status, dental treatment needs, and DoD dental readiness classification. The 2008 survey, conducted on a random sample of 5,835 personnel, identified 4.2% of patients as DoD Dental Class 1, 43.4% as Class 2, and 52.4% as Class 3. Figure 1 illustrates the distribution of DoD dental classification status among U.S

military recruits for each of the recruit surveys conducted by TSCOHS. In general, the values for DoD Dental classification have stayed very consistent.

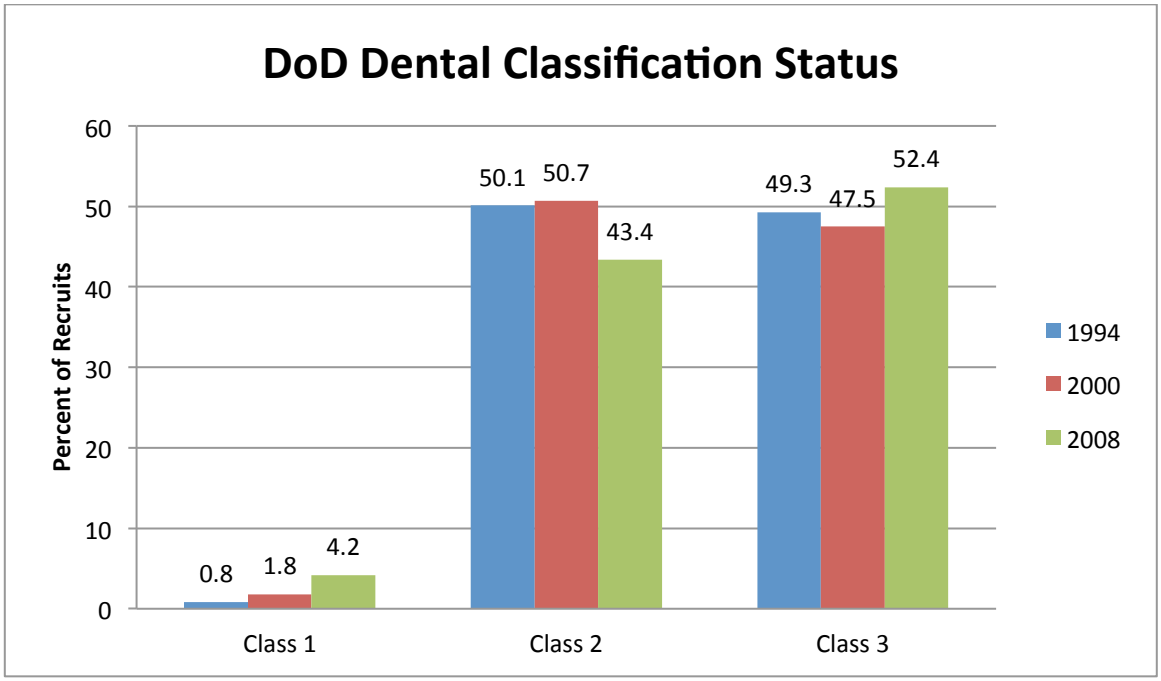


Figure 1. Distribution of Dental Classification status among DoD recruits, 1994, 2000, and 2008.*

*Adapted from Leiendecker and colleagues (2009, 2011). Used with permission.

In all three TSCOHS surveys, dental caries and oral surgical treatment needs were the leading causes for recruits to be classified Dental Class 3 (Leiendecker and colleagues, 2009, 2011). Figure 2 illustrates the distribution of restorative treatment need for each survey year by Dental Class. Values for DoD Dental classification in figure 2, like figure 1, have stayed very consistent since 1994 demonstrating that there has not been an appreciable decline in caries rate in the military recruit population for at least 14 years.

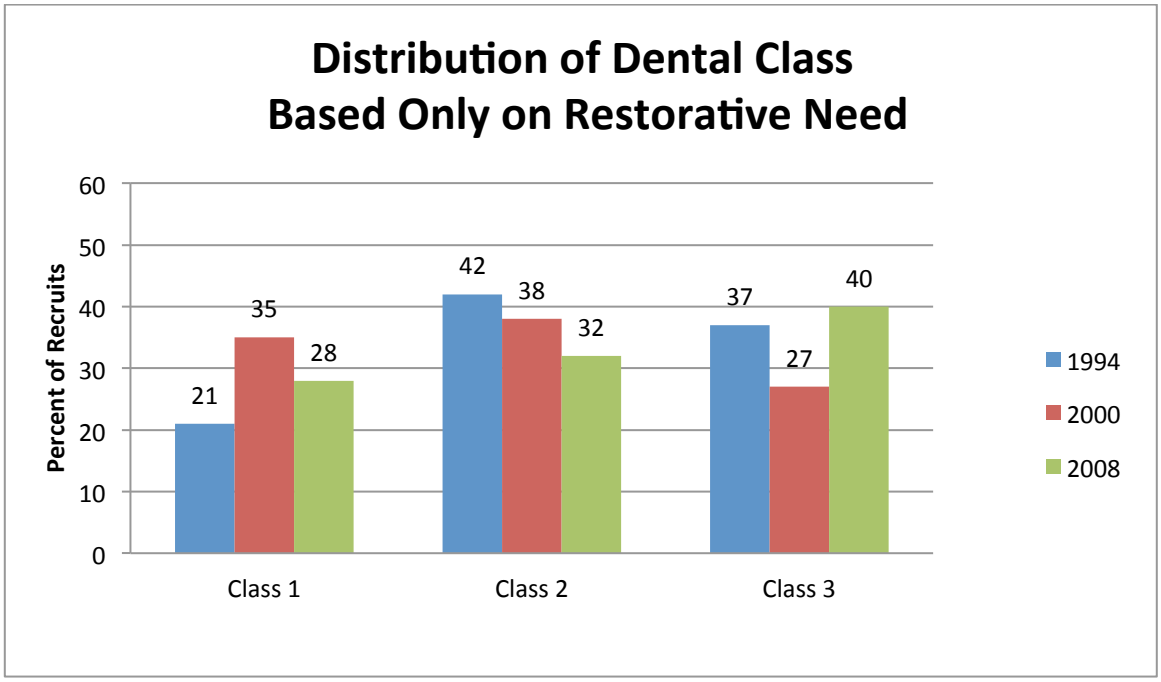


Figure 2. Distribution of Dental Class by restorative treatment need among DoD recruits in 1994, 2000, and 2008.*

*Adapted from Leiendecker and colleagues (2009, 2011). Used with permission.

Although most incoming recruits had evidence of previous dental caries (e.g., dental restorations), approximately one fifth to one-third had no caries-related treatment need at initial examination (20.6% in 1994; 34.4% in 2000; 28% in 2008) Most recruits required three or fewer restorations. However, nearly 30% (2000) to 40% (1994 and 2000) required four or more restorations; and in 2008, 18.1% of incoming recruits presented with seven or more untreated caries lesions (Figure 3).

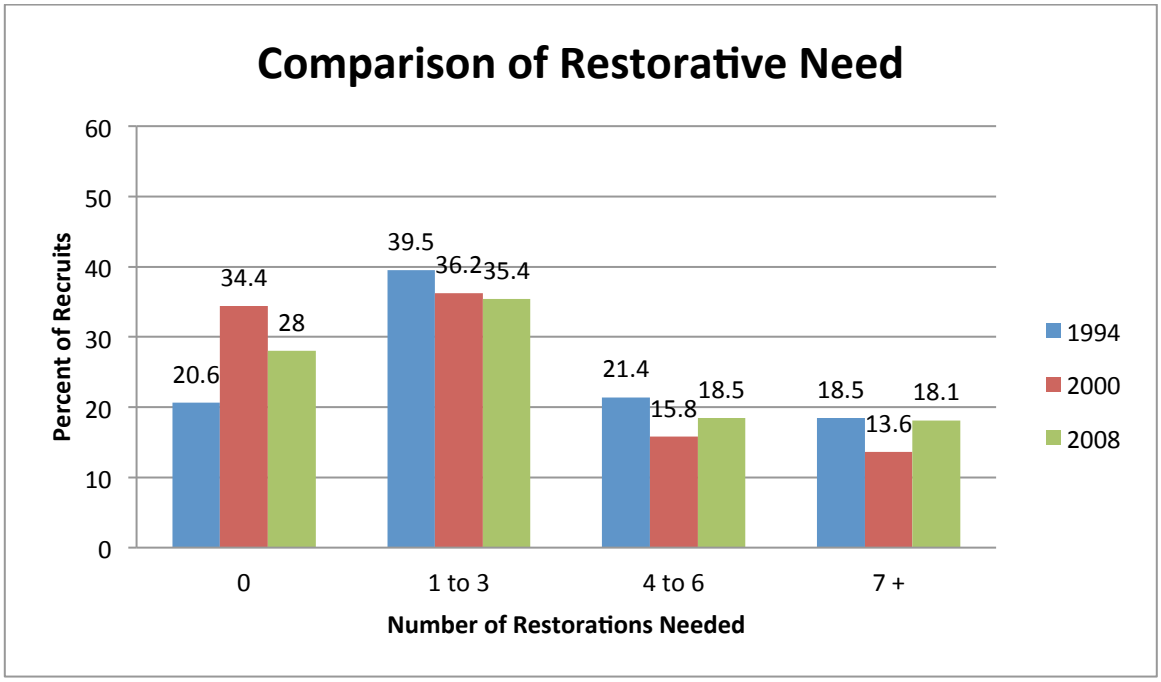


Figure 3. Number of restorations needed per patient at initial examination (among all personnel) (1994, 2000, 2008)*

*Adapted from Leiendecker and colleagues (2009, 2011). Used with permission.

Among personnel who exhibited dental caries, most required only one to three restorations (49.8% of recruits in 1994; 55.2% in 2000; 49.1% in 2008). However, a substantial number of recruits exhibited extensive dental caries (i.e., 7 or more teeth requiring restorations) (23.3% in 1994; 20.6% in 2000; 25.2% in 2008) (Leiendecker & colleagues, 2009, 2011). Figure 4 shows the distribution of restorative treatment need among personnel requiring restorations. Again, the relative treatment need has stayed consistent with time.

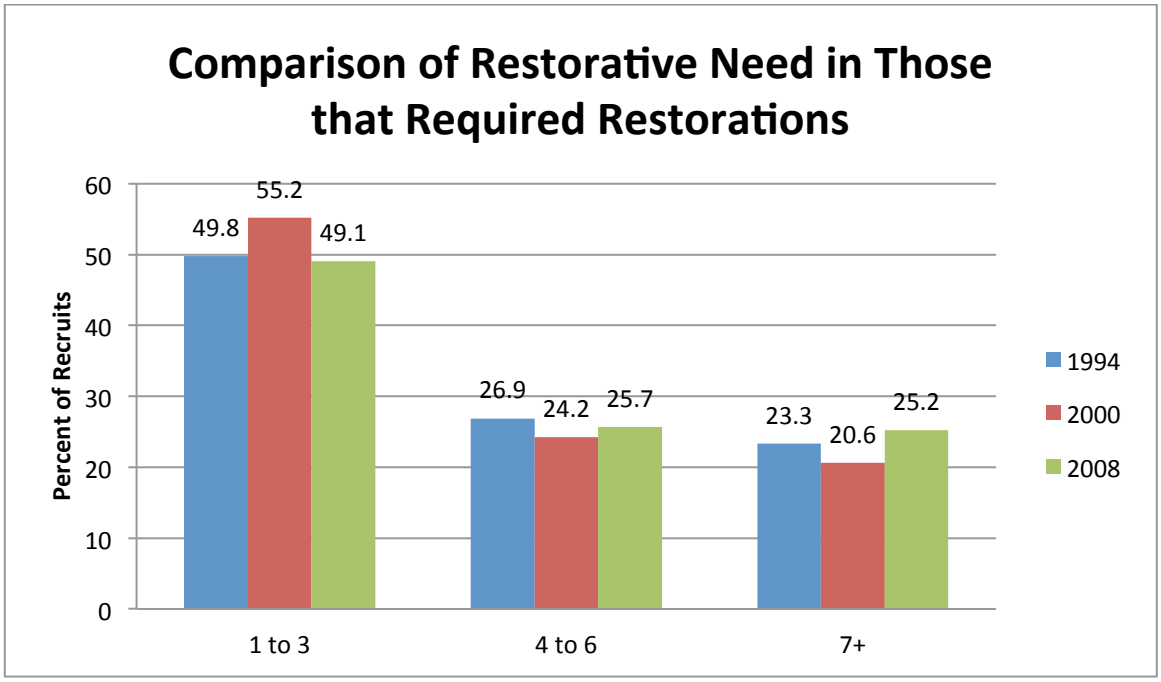


Figure 4. Number of restorations needed per patient at initial examination (among personnel requiring restorations, 1994, 2000, 2008)*

*Adapted from Leiendecker and colleagues (2009, 2011). Used with permission.

SUMMARY

Dental caries is a complex disease of multi-factorial etiology. Once ubiquitous in industrialized societies, the prevalence of dental caries in the U.S. has decreased by over 30% since the introduction of public water fluoridation and fluoridated toothpastes in the 1950s and 1960s. However, in spite of this decline, only 15% of 17-year-olds are caries-free, and most adults – over 90% – have had at least one caries lesion or dental restoration. Furthermore, the decline in caries experience has not been uniform across all socio-demographic groups; while some groups exhibit minimal caries experience, 60% of all caries lesions now occur in only 20% of the population. Therefore, a method to accurately identify those individuals at risk for future caries experience would be extremely valuable. In addition, if this model could assess caries risk without using

previous caries experience as a marker (i.e., before the occurrence of a patient's first caries lesion), it may allow for the truly proactive delivery of preventive dental therapies.

The literature suggests that caries prediction models can be quite complex, and that models targeted to discreet homogeneous population subgroups, rather than entire populations, may be more accurate. Based on their average age (19.2), limited educational background, and predominance (82%) of male members, U.S. military recruits represent a unique subset of the general population that exhibits multiple characteristics associated with increased caries risk. Moreover, based on the data obtained from three TSCOHS surveys (1994 – 2008), it is evident that many recruits enter the armed services with significant dental need (72% required at least one restoration, and 18% required 7 or more restorations in 2008).

In addition to assessing treatment need, the 2008 TSCOHS Recruit Oral Health Survey administered to each recruit a 37-item questionnaire addressing socio-demographic factors, dietary habits, oral hygiene practices, tobacco use, and dental experiences prior to enlistment. To date, these data have not been analyzed, and little research has evaluated specific caries risk factors among this age group. Identifying variables that may predict future caries experience may improve both cost-effectiveness and therapeutic benefit of dental care provided for this military population. Therefore, using data from the 2008 TSCOHS Recruit Oral Health Survey, the purpose of this study was to determine if caries prevalence and caries risk status among US military recruits correlate with various specific socio-demographic, clinical, and behavioral factors.

CHAPTER II: MATERIALS AND METHODS

The 2008 TSCOHS Recruit Oral Health Survey was conducted from December 2007 through November 2008 at nine military recruit training facilities throughout the United States (one U.S. Air Force site, five U.S. Army sites, two U.S. Marine Corps sites, and one U.S. Navy site). Dental examinations included detailed recording of current oral disease and treatment needs (restorative, endodontic, periodontic, oral surgery, and prosthetic), as well as the presence and condition of pre-existing restorations. Data were entered into laptop computers utilizing a proprietary software program designed by the TSCOHS specifically for data collection for the 2008 Oral Health Survey. Twelve calibrated dental examiners (three U.S. Air Force; five U.S. Army; four U.S. Navy) conducted all dental examinations. A total of 5,835 recruits were examined to provide a representative sample of an estimated total population of 300,418 recruits (Leiendecker & colleagues, 2009, 2011). Personal identifiers were removed from all data to protect subject anonymity. Informed consent was obtained from all participants prior to enrollment in the study. The research protocol for the 2008 Oral Health Survey was reviewed and approved by the Institutional Review Board of the Uniformed Service University of the Health Sciences (USUHS, and received local approval from the Commanding Officer at each recruit training facility.

DATA COLLECTION

Data collected from 5,835 recruits (1,100 U.S. Navy, 1,200 U.S. Marine Corps, 1900 U.S. Army, 1500 U.S. Air Force) were reviewed. Gender, race, and age at in-processing, were determined from patient-reported information recorded during the initial dental examination. Periodontal status was determined from PSR scores recorded by the

examining dentist during the initial examination. Dietary habits and tobacco use as reported at in-processing were determined from responses to a validated survey questionnaire completed by the patients immediately prior to their dental examinations.

The current study evaluated the previously collected data from the dental examinations and survey questionnaires to determine associations between dental caries experience and specific socio-demographic, clinical, and behavioral factors. No new data were collected during this study.

STATISTICAL ANALYSIS

Data were analyzed using Statistical Package for the Social Sciences (SPSS) Version 14 computer software. Stepwise linear regression analysis was used to determine associations between dental caries prevalence and the following factors and characteristics:

- Gender
- Race
- Age at in-processing
- Tobacco use (as reported at in-processing)
- Periodontal status at in-processing
- Dietary habits at in-processing (based on Survey questionnaire)
- Oral hygiene practices (based on Survey questionnaire)
- Prior dental history (based on Survey questionnaire)
- Education Level

All statistical significance levels were set at $\alpha = 0.05$.

HUMAN SUBJECT USE

The protocol for this study was reviewed and approved by the Institutional Review Boards (IRB) for the Naval Postgraduate Dental School and the Uniformed Service University of the Health Sciences (USUHS). All investigators completed the "Collaborative IRB Training Initiative" (CITI) to ensure compliance with the requirement for protection of human research subjects.

CHAPTER III: RESULTS

Of the 5,835 recruits surveyed, 81.2% were male and 17.9% female. The race/ethnicity distribution for the DoD recruits was 66.4% white, 15.4% black, 11.4 % Hispanic, 3.5% asian, and 3.4% other. Age distribution showed that over 45% of the recruits were 18 to 19 years of age and 37% were ages 20-24.

Figure 5 illustrates the range of restorative treatment need, based on the number of caries lesions documented for this recruit population. The number of caries lesions identified ranged from zero to 27, with a mean of 3.4 (± 3.89) lesions per recruit.

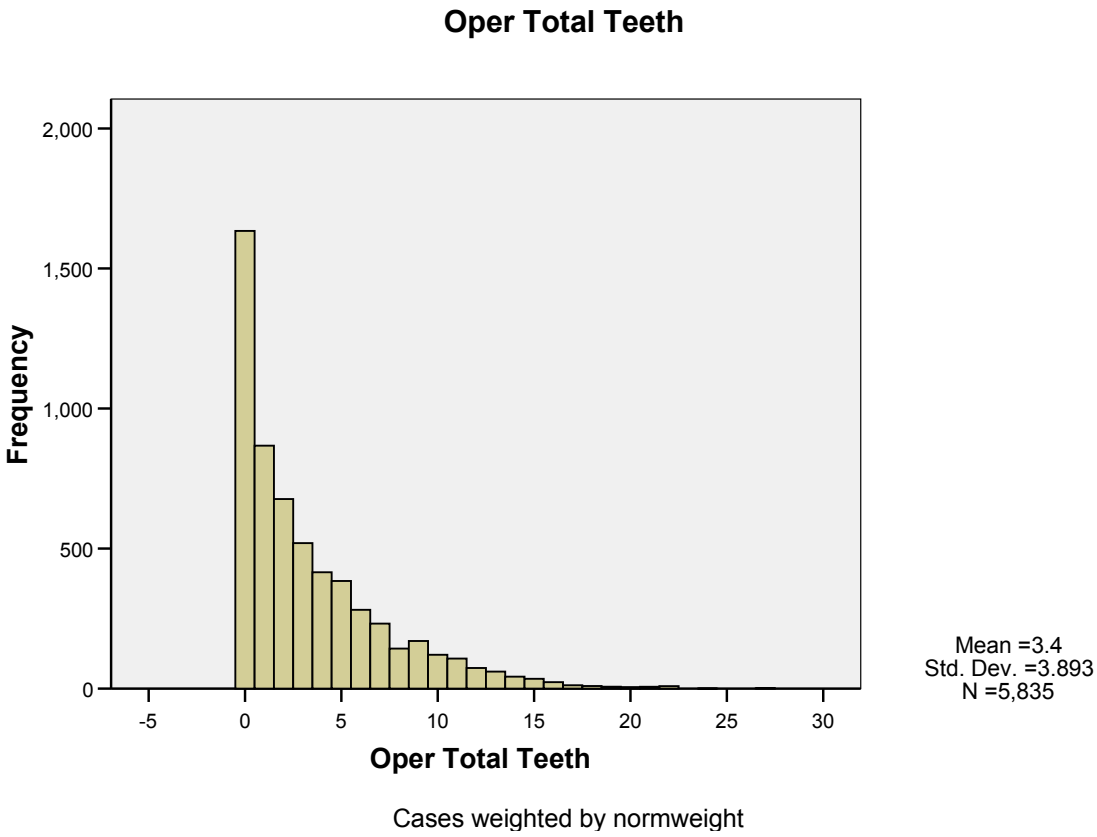


Figure 5. Distribution of restorative treatment need.

Regular soda consumption between meals was significantly associated with caries prevalence ($p < 0.001$). Figure 6 demonstrates the frequency of regular soda consumption in this recruit population. Average daily consumption of regular soda between meals was 2.02 (± 1.40) sodas per recruit per day. Eleven percent of the population reported zero regular soda consumption between meals, whereas 89 percent reported consuming at least one regular soda between meals every day.

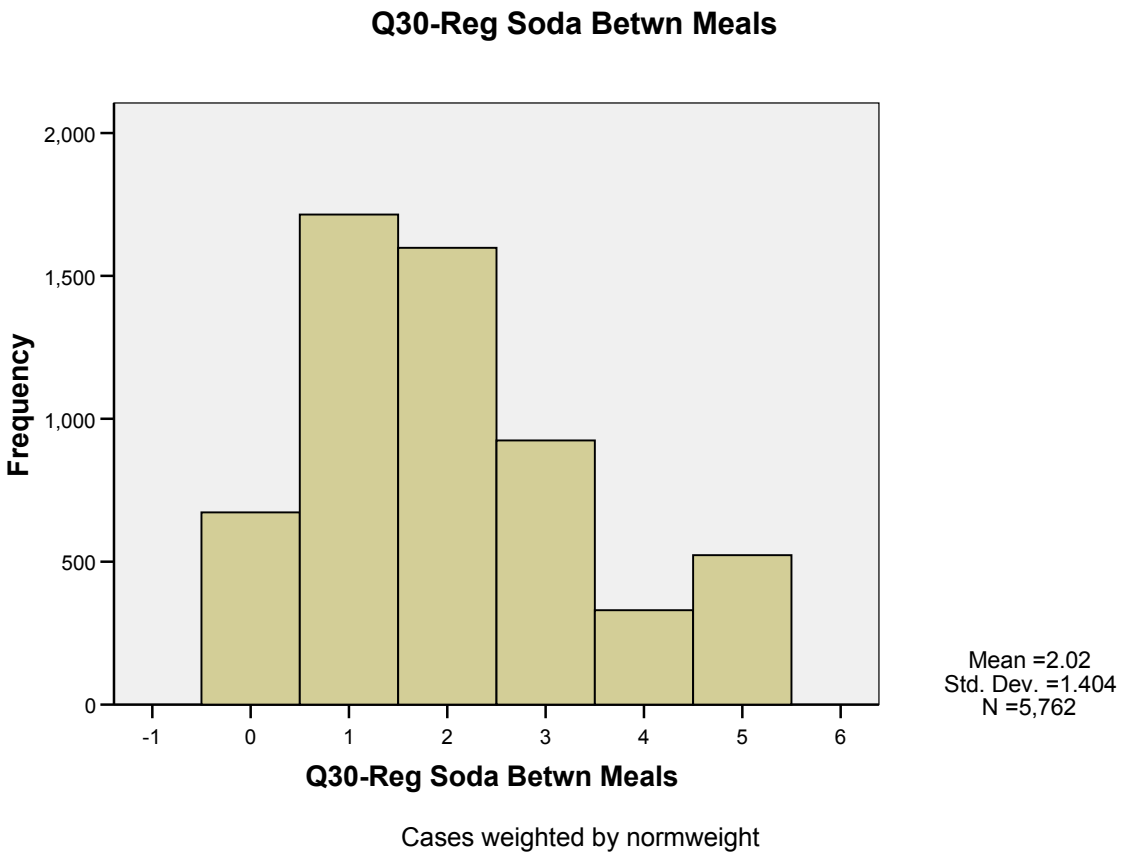


Figure 6. regular soda consumption between meals

Figure 7 shows the relationship of regular soda consumption between meals and the recruits' operative need. The Tukey HSD test demonstrates differences among three

groups. Those groups include 0-1 soda between meals, 1-2 sodas between meals, and 3 sodas or more between meals. The difference between not consuming any sodas between meals and consuming more than 5 sodas between meals is 1.63 lesions per recruit.

Operative Total Teeth

Regular Soda Between Meals	N	Subset 1	2	3
0	690	2.52		
1	1751	2.77	2.77	
2	1605		3.11	
3	914			3.70
4	328			3.89
5 or more	479			4.15
Sig.		.835	.562	.253

Figure 7: Relationship between regular soda consumption and operative need

Cigarette smoking was one of the behaviors most significantly associated with caries prevalence ($p < 0.001$). Figures 8 demonstrates the number of cigarettes smoked on average in a 24 hour period per recruit. Forty-one ($n = 2,373$) percent of the recruit population reported smoking at least 100 cigarettes in their lifetimes. Among DoD recruits who reported smoking, average consumption was 4.2 cigarettes per day. Of those who reported smoking, smoking 10 cigarettes and 20 cigarettes per day were the most common answers (Figure 8).

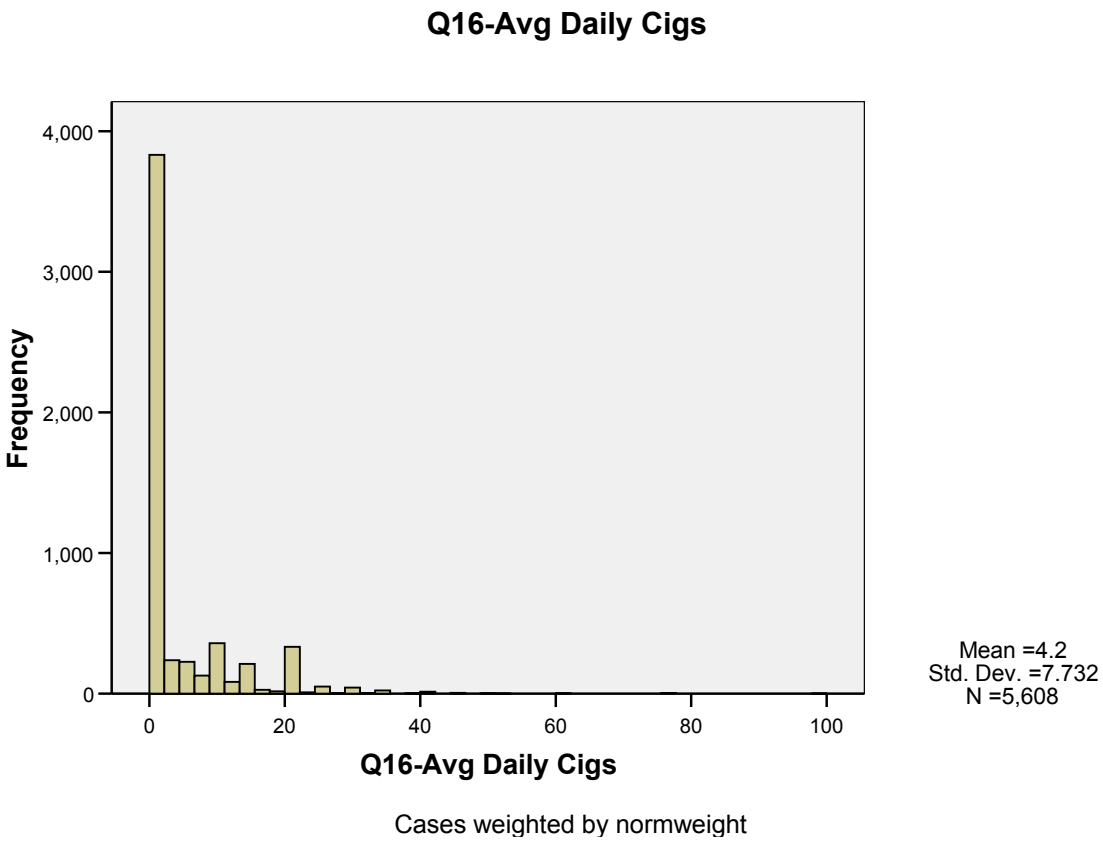


Figure 8. Self-reported daily cigarette smoking frequencies among DoD recruits.

Figure 9 illustrates the difference in caries experience based on smoking one or more cigarettes per day versus not smoking. Non smokers had an average of 2.84 caries lesions per recruit, while recruits that reported smoking at least one or more cigarettes per day had an average of 3.84 caries lesions. Smoking only one cigarette a day resulted in a difference of one caries lesion per recruit.

	Q16-Avg Daily Cigs	N	Mean	Std. Deviation	Std. Error Mean
Oper Total Teeth	>= 1	1844	3.84	4.312	.100
	< 1	3765	2.84	3.487	.057

Figure 9. Caries experience related to smoking 1 cigarette a day versus non-smoking.

Among this recruit population, the time since last dental visit had a statistical significance P value of <0.001 for caries prevalence. Figure 10 illustrates the percentage of recruits who had last visited the dentist within 5 different groups. Over 40% of the population had seen a dentist within 12 months immediately preceding enlistment; 1.9% reported having never seen a dentist.

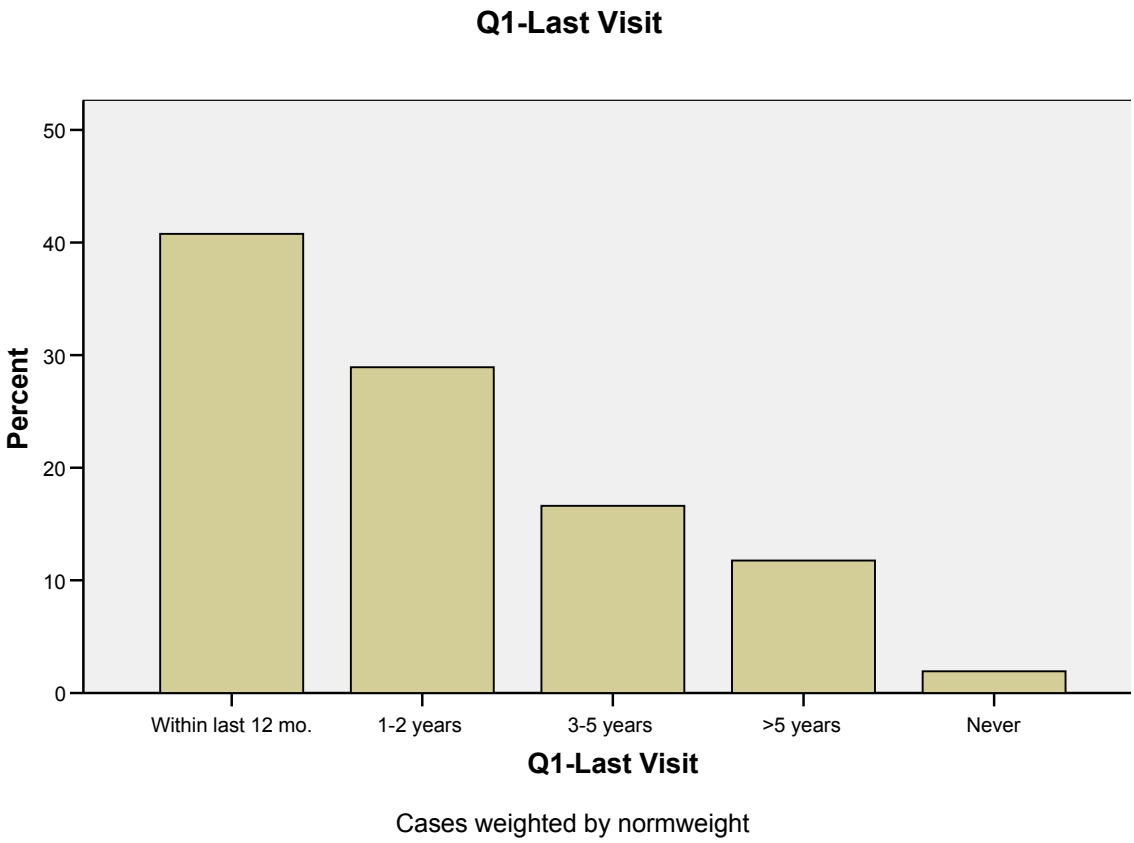


Figure 10. Time since last dental visit.

Figure 11 illustrates the percentage of recruits within each caries experience group and their last dental visit. On average most recruits had seen a dentist within 12 months regardless of caries incidence. However, as caries experience increased, so too did the proportion of recruits who reported not seeing a dentist for at least 3 years. Only

21% of recruits with zero caries hadn't seen a dentist within 3 years, whereas over 34% of recruits with more than 7 caries hadn't seen a dentist within 3 years.

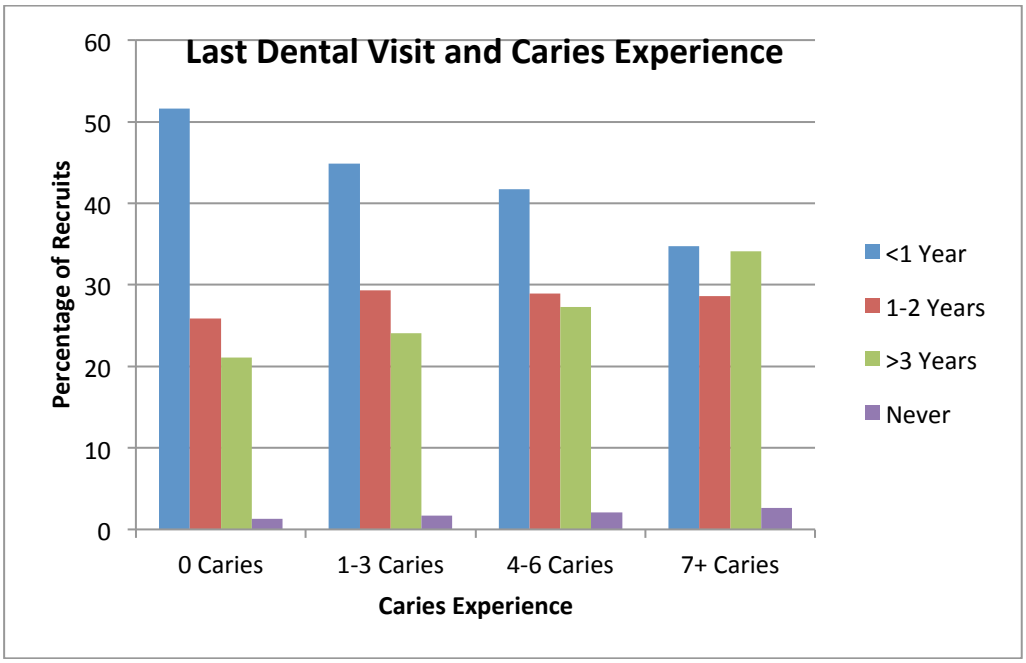
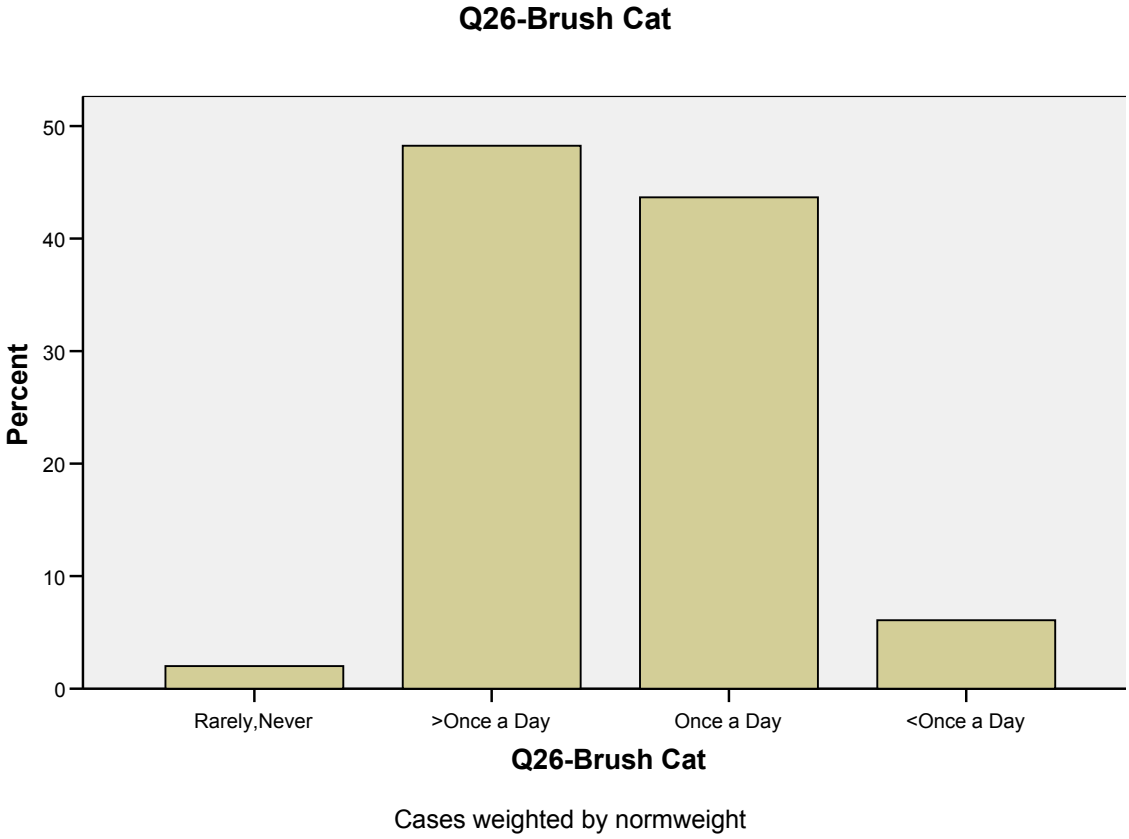


Figure 11. Time since last dental visit and caries experience

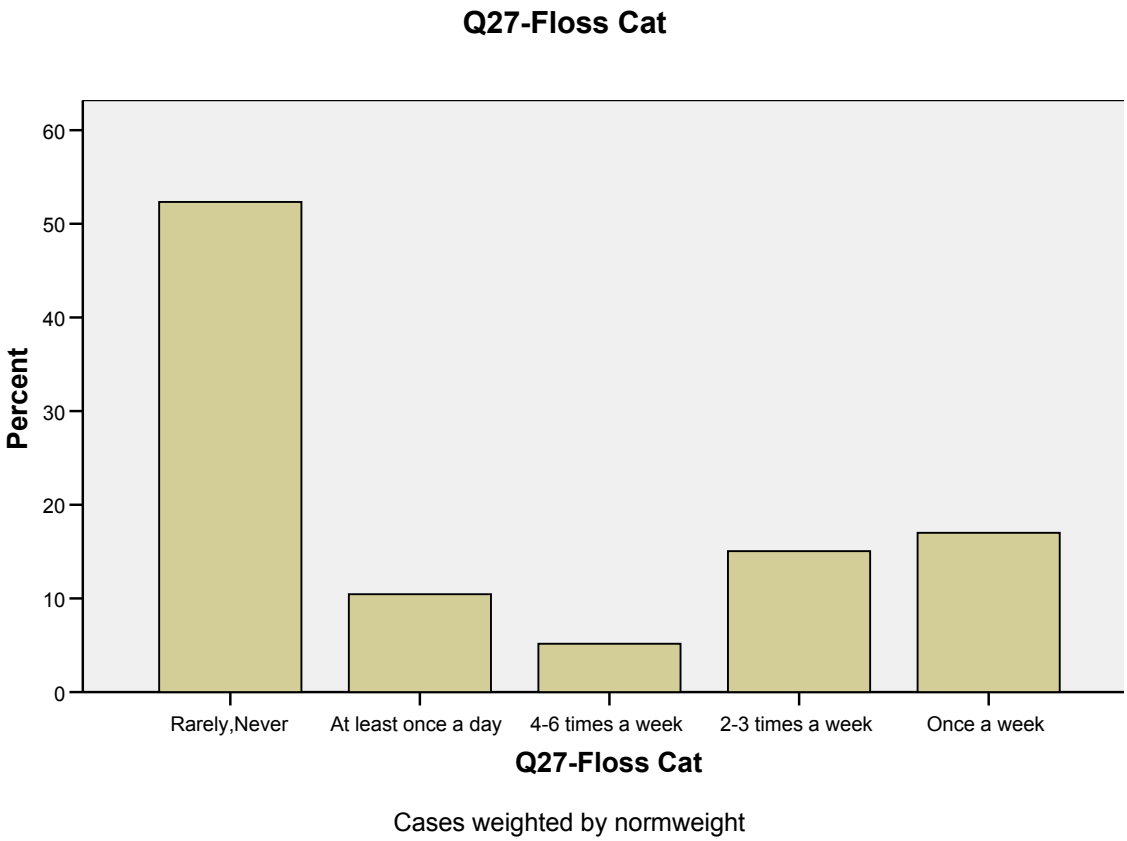
Brushing frequency had a significance P value of 0.005. Figure 12 illustrates the range in frequency of self-reported daily tooth brushing. The vast majority of recruits, 91 percent, reported brushing once a day or more; only 2 percent reported never or rarely brushing. Caries prevalence among DoD recruits who reported brushing at least once per day was 2.88 caries lesions, while those who reported brushing less than once per day exhibited 4.29 caries lesions.

Figure 12. Frequency of tooth brushing



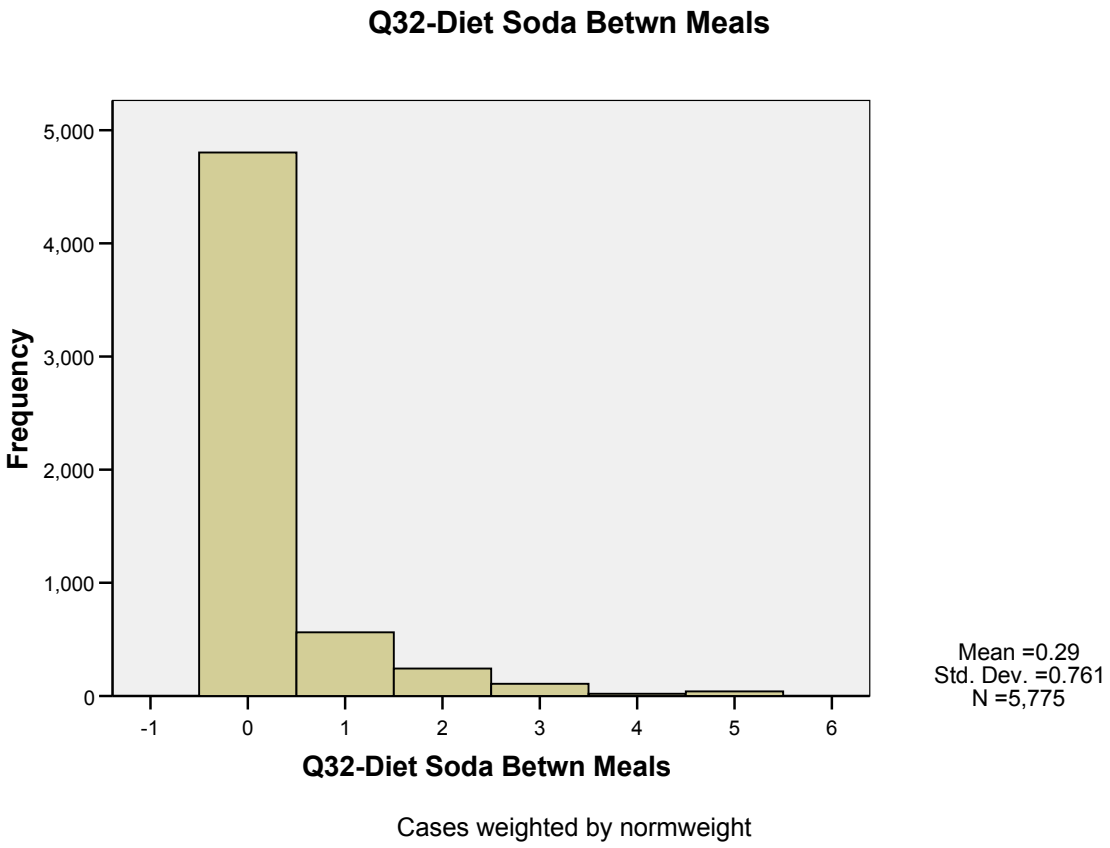
The self-reported behavior of flossing was not statistically significant in relation to caries prevalence (p = 0.184). Figure 13 demonstrates the frequency of flossing in our recruit population. Nearly 52% of the population reported rarely or never flossing their teeth. The second largest group, 17 percent, reported flossing once a week or less; 10 percent reported flossing every day.

Figure 13. Flossing frequency



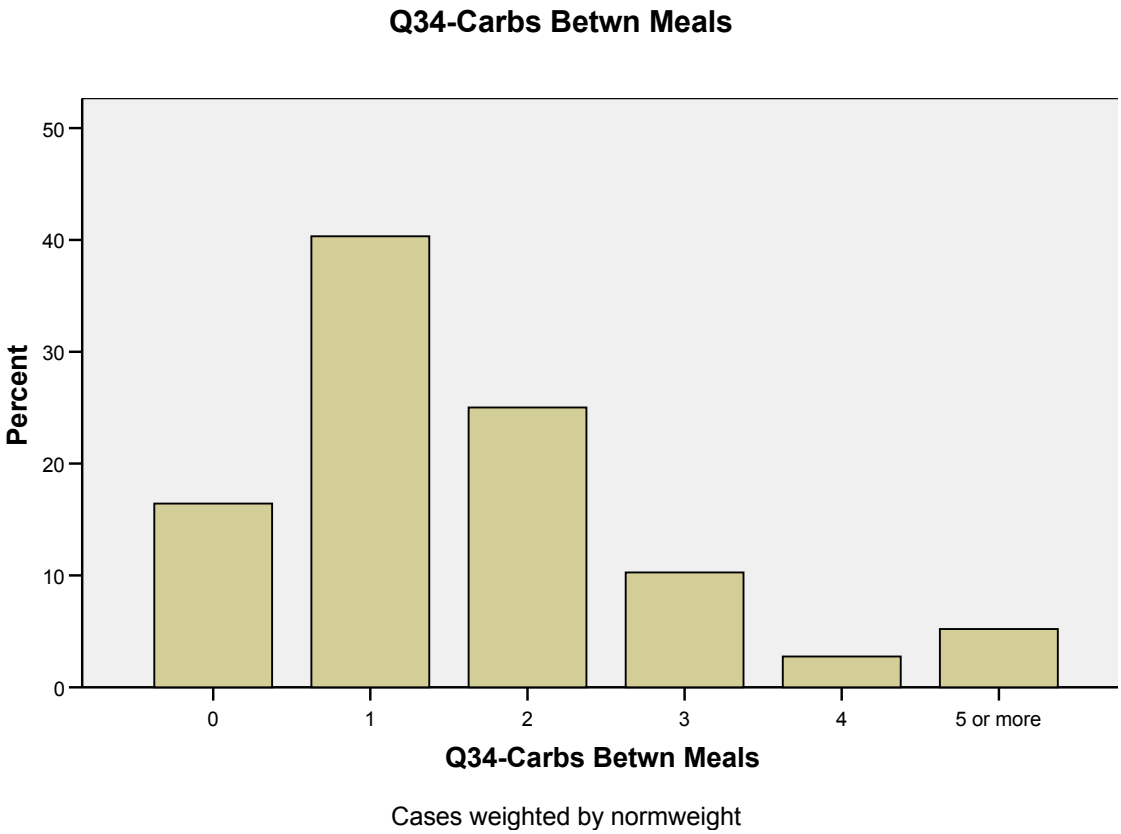
The frequency of diet soda consumption between meals was not statistically significant in relation to caries prevalence ($p = 0.951$). Figure 14 illustrates the frequency of diet soda consumption between meals; 82 percent of the recruit population reported consuming no diet soda between meals. Average caries experience for recruits who reported not drinking any diet soda between meals was 2.63, while those recruits reporting 5 diet soda drinks between meals had an average of 3.5 caries.

Figure 14. Frequency of diet soda consumption between meals.



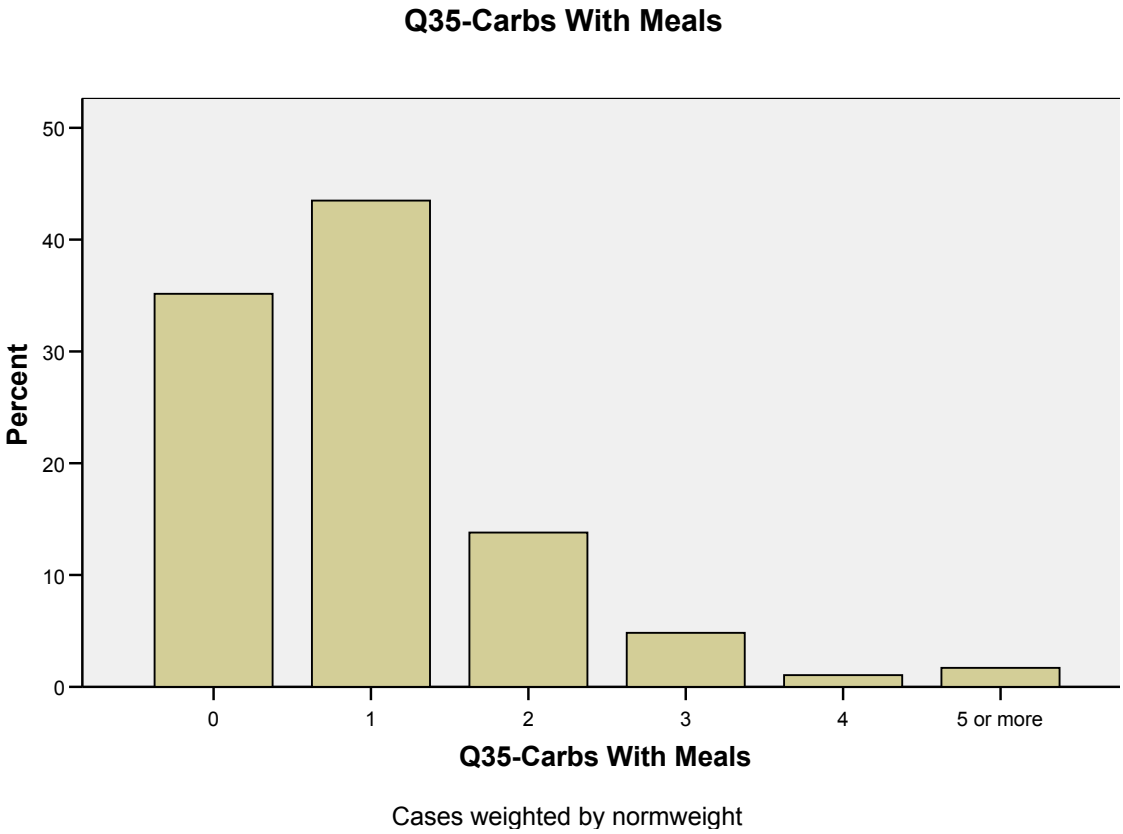
Consuming sugary snacks between meals was significantly associated with caries prevalence ($p = 0.006$). Figure 15 illustrates the frequency of sugary snack consumption between meals in our recruit population. Only 16 percent of the recruit population reported eating zero sugary snacks between meals each day, while 65 percent reported eating 1-2 sugary snacks between meals a day. Recruits who reported not consuming any sugars snacks between meals had an average of 2.2 caries lesions, while recruits who reported having at least 5 sugary snacks between meals had an average of 3.6 caries lesion. In addition, recruits who reported having only one sugary snack between meals per day had an average of 3.2 caries lesions.

Figure 15. Frequency of sugary snacks between meals.



In contrast, consuming sugary snacks with meals was not a statistically significant risk factor in caries prevalence ($p = 0.702$). Figure 16 illustrates the frequency of sugary snacks consumed with meals per recruit per day. Sixty-five percent of the population reported having at least one sugary snack with a meal each day; 56 percent reported consuming 1-2 sugary snacks with meals per day. Caries experience was 3.4 among those who consumed sugary snacks with meals and 3.4 among those who did not.

Figure 16. Sugary snacks with meals



Using linear regression analyses, a caries prediction model was developed. Five main risk categories were identified as being significant predictors for caries prevalence. Those factors included: Tobacco use (both smoking, and smokeless), time since last dental visit, regular soda between meals, brushing frequency, and sugary snacks between meals. Table 2 shows these specific risk factors and their respective significance value.

Table 2. Linear regression model of behaviors significantly associated with caries prevalence.

Factor	P Value
Avg daily cigarettes	< 0.001
Last dental visit	< 0.001
Regular soda consumption between meals	< 0.001
Smokeless tobacco user	0.001
Brushing frequency	0.005
Sugary snacks between meals	0.006
Smoker	0.006

Other self-reported behaviors did not demonstrate statistically significant associations with caries prevalence in this population. These factors included: gender, regular soda consumption with meals, diet soda consumption (with or between meals), sugary food consumption with meals, and flossing frequency. Table 3 lists these factors and their corresponding significance values.

Table 3: Linear regression model of behaviors not significantly associated with caries prevalence.

Factor	P Value
Gender	0.425
Regular soda consumption with meals	0.940
Diet soda consumption with/without meals	0.951
Sugary food consumption with meals	0.702
Flossing frequency	0.184
Fruit/Vegetable servings	0.400
Dairy servings	0.467

CHAPTER IV: DISCUSSION

The objective of this study was to determine if dental caries prevalence and caries risk status among U.S. military recruits correlated with certain self-reported socio-demographic, clinical, and behavioral factors collected from a 37-item survey questionnaire administered during the 2008 TSCOHS Recruit Oral Health Survey.

Comparing caries experience of a military recruit population to a similar civilian counterpart, demonstrates a significant increase in diseases surfaces in the military population. Results from the NHANES studies demonstrated the mean number of diseased surfaces for adults in the civilian population aged 18-45, was 1.82 as reported from 1988-1994. In comparison, the mean number of diseased surfaces in this recruit population was 3.4; a number which has remained fairly constant since 1994. This leads us to conclude that the military recruit population enters military service at an increased caries risk compared to their civilian counterparts.

Stepwise linear regression analyses revealed a caries predictive model with eight risk behaviors that encompassed five main risk categories. The five main risk categories included: Tobacco use (both smoking, and smokeless), regular soda consumption between meals, sugary snacks between meals, time since last dental visit, and brushing frequency.

In the dental literature, tobacco use (smoking and smokeless) has shown equivocal results in relation to influencing caries risk.

A recurring theme of increased caries risk was demonstrated when a sugar source between meals was consumed. This agrees closely with other reported research that suggests the frequency of sugar consumption is more important than the quantity of sugar

consumed in determining caries risk (Burt and Eklund, 2005, Gustaffson & colleagues, 1954; Krasse, 2001). Frequent sugar consumption creates a drop in pH in the oral environment, which can lead to the development of caries. This phenomenon was first described in the 1940s by Stephan (1940). The Stephan Curve is characterized by an immediate, rapid drop in plaque pH when a patient is exposed to an oral glucose solution which is attained within a very few minutes. This is followed by a slower rise taking anywhere from 15 to 40 minutes until the resting pH is attained. The time course varies between individuals, and the nature of the challenge (Stephan 1940). Specifically, patients with active caries have a lower resting pH level in their oral cavity, experience a greater overall drop in pH when exposed to an oral glucose solution, and the duration of time required to return to resting levels is increased. Figure 17 illustrates this phenomenon.

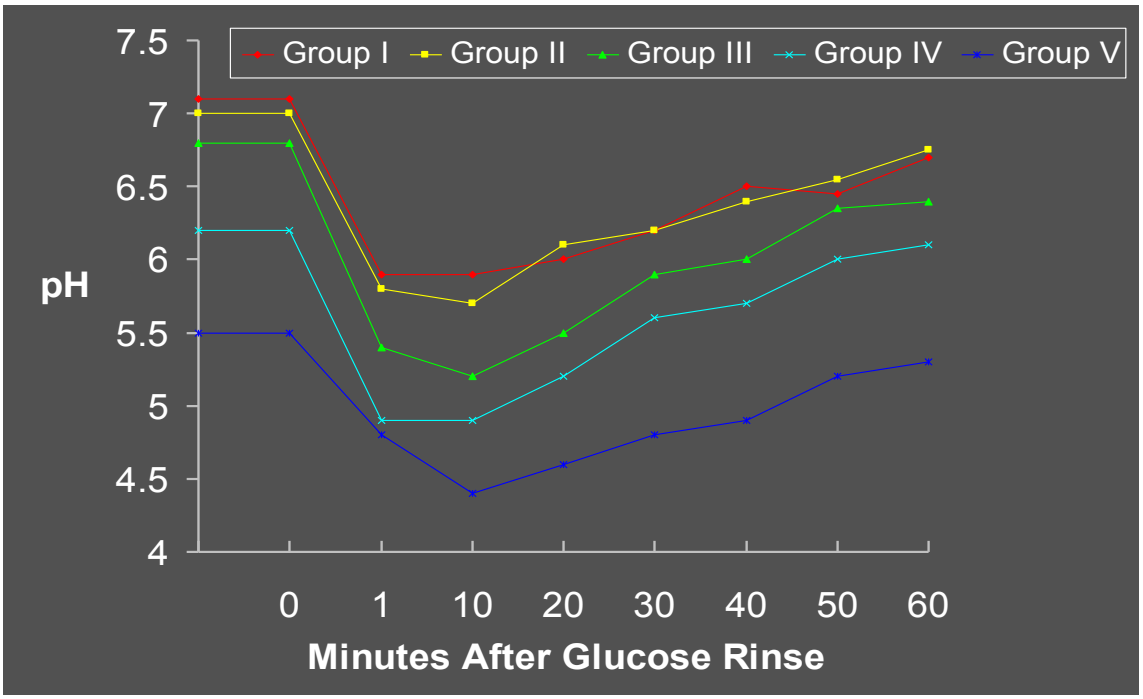


Figure 17. Stephan curve illustrating plaque pH response to sucrose exposure.

Dental literature has shown that consuming sugary foods with meals, rather than between meals, can lessen the caries risk. The Vipeholm study demonstrated that it was possible to increase the average sugar consumption (from about 30 to 330 g/day) with very little increase in caries experience (from 0.27 to 0.43 new carious surfaces/year), provided the additional sugar was consumed at meals in solution, rather than in solid form between meals (Burt & colleagues, 1988). Other research has shown a marked decrease in caries experience when dietary consumption is severely restricted. In the late 1950s, institutionalized children at Hopewood House in Bowral, Australia, did not receive refined carbohydrates starting from birth. The carbohydrates they did consume were in the form of whole-meal bread, soya beans, wheat germ, oats, rice, potatoes, and molasses (Harris, 1963). Dental surveys of these children at the ages of 5 and 13 revealed an average DMFT score of 1.1, or about 10% of the caries prevalence in the general population of those age groups. The fluoridation level of the water was 0.1ppm and the oral hygiene of the children was poor; about 75% suffered from gingivitis. As the children grew older, however, they were relocated and their diets changed. As a result, most exhibited a sharp increase in caries experience after 13 years of age, with DMFT scores soon mirroring those of the majority of Australian teenagers (Newbrun, 2003).

Results showed that the time since last dental visit was related to caries experience, with the longer the duration of time the higher average mean caries experience.

Brushing frequency was a significant factor in caries experience. As stated above, caries prevalence among DoD recruits who reported brushing at least once per day was

2.88 caries lesions, while those who reported brushing less than once per day exhibited 4.29 caries lesions. However, as previous research has shown, it is more likely that this protective factor is from the frequent introduction of fluoride rather than the mechanical removal of plaque (Burt and Eklund 1992).

In general, the highest risk factors identified by this research coincide with much that has been reported in the dental literature. The lone exception being the strong correlation of tobacco use and caries experience in our recruit population. These findings do not suggest any huge changes are needed in the education and management of our patients, but a clinical use for these findings could be to emphasize the five main risk behaviors identified with our patients as these risk behaviors in combination are highly correlated with caries experience.

Several limitations to this study have been identified. In particular the information collected from the survey is retrospective in nature. As a result we were not able to ask patients for clarification on their answers. In addition, some recruits did not answer all 37 items on the questionnaire, and we are unable to know if the omissions were intentional or unintentional.

CHAPTER V: CONCLUSION

In this study, based on a 37-item questionnaire, several risk behaviors were significantly associated with caries experience. The three most statistically significant factors were smoking, time since last dental visit, and the consumption of regular soda between meals. Based on these results, it would seem wise to continue advising our patients on dietary habits, offer tobacco cessation information, and recommend frequent visits to their local general dentist. In particular, it may be wise to focus more attention on the risk factors identified here as they have been specifically obtained from our military patient population, which is a unique subset of the population at large.

A highly accurate and predictive model of future caries experience still does not exist today. More research is needed in the area of behavioral risk factors to determine their efficacy in predicting future caries risk. Specifically, how accurate can a model with these risk factors, in a military population, be at predicting future caries risk. A prospective study analyzing patient behavior and caries experience may shed more light on predictive capability as opposed to a retrospective study. Ultimately, it may be that our current model of looking at, a combination of known risk behaviors and previous caries experience, continues to best serve our community in identifying those at increased caries risk; however, the precision of this identification may be increased by continuing to evaluate and do research on the accuracy of specifically defined risk behaviors.

APPENDIX A

U.S. Naval Oral Disease Risk Management Guidelines

Caries Risk Status	Criteria
Low	No new incipient or cavitated primary or secondary caries lesions during current exam; AND No factors that may increase caries risk.
Moderate	One or two new incipient or caviated primary or secondary caries lesions during current exam; OR No incipient or caviated primary or secondary caries lesions during current exam, but presence of at least one factor that may increase caries risk
High	Three or more new incipient or cavitated primary or secondary caries lesions during current exam; OR Presence of multiple factors that may increase caries risk.
Source: BUMED Instruction 6600.16A, 23 August 2010.	

REFERENCES

1. Alanen P, Hurskainen K, Isokangas P, Pietila I, Levänen J, Saarini USm Tiekso J (1994). Clinician's ability to identify caries risk subjects. *Community Dentistry and Oral Epidemiology 22*(2); 86-89.

2. Antoft P, Rambusch E, Antoft B, Christensen HW (1999). Caries experience, dental health behavior and social status-three comparative surveys among Danish military recruits in 1972, 1982, 1993. *Community Dental Health 16*(2): 80-84.

3. Bader J, Graves R, Disney J, Bohannan H, Stamm J, Abernathy J, Lindahl R (1986). *Community Dentistry and Oral Epidemiology 14*(4): 198-201.

4. Beck J (1990). Identification of risk factors. In Bader JD (ed.). Risk assessment in dentistry: Proceedings of a conference. Chapel Hill: University of North Carolina School of Dentistry Department of Dental Ecology, pp. 8-13.

5. Beighton D, Adamson A, Rugg-Gunn A (1996). Associations between dietary intake, dental caries experience and salivary bacterial levels in 12-year-old English schoolchildren. *Archives of Oral Biology 41*(3): 271-280.

6. Beltran-Aguilar ED, Barker LK, Canto MT, Dye BA, Gooch BF, Griffin SO, Hyman J, Jaramillo F, Kingman A, Nowjack-Raymer R, Selwitz RH, Wu T (2005). Surveillance for dental caries, dental sealants, tooth retention, edentulism, and enamel fluorosis – United States, 1988-1994 and 1999-2002. MMWR Surveillance Summaries *54*(3): 1-44.

7. Brown LJ, Wall TP, Lazar V (2002). Trends in caries among adults 18 to 45 years old. *Journal of the American Dental Association 133*(7): 827-834.

8. Brunelle JA, Carlos JP (1990). Recent trends in dental caries in US children and the effects of water fluoridation. *Journal of Dental Research 69*(Spec Iss): 723–727.

9. Burt BA, Eklund SA, Morgan KJ, Larkin FE, Guire KE, Grown LO, Weintraub JA (1988). The effects of sugars intake and frequency of ingestion on dental caries increment in a three-year longitudinal study. *Journal of Dental Research 67*(11): 1422-1429.

10. Burt BA, Pai S (2001). Sugar consumption and caries risk: A systematic review. *Journal of Dental Education 65*(10); 1017-1023.

11. Disney J, Graves R, Stamm J, Bohannan H, Abernathy J (1990). The University of North Carolina Caries Risk Assessment Study. II. Baseline Caries Prevalence. *Journal of Public Health Dentistry 50*(3): 178-185.

12. Disney J, Graves R, Stamm J, Bohannan H, Abernathy J, Zack D (1992). The University of North Carolina caries risk assessment study: Further developments in caries risk prediction. *Community Dentistry and Oral Epidemiology 20*(2), 64-75.

13. Disney J, Stamm J, Graves R, Bohannan H, Abernathy J, Zack D (1990). In Bader JD, ed. Risk assessment in dentistry: Proceedings of a conference, Chapel Hill: University of North Carolina School of Dentistry Department of Dental Ecology, pp. 204-213.

14. Dye BA, Areval O, Vargas CM (2010). Trends in paediatric dental caries by poverty status in the United States, 1988 – 1994 and 1999 – 2004. *International Journal of Paediatric Dentistry 20*(2): 132-143.

15. Dye BA, Thornton-Evans G (2010). Trends in oral health by poverty status as measured by Healthy People 2010 objectives. *Public Health Reports 125*(6): 817-830.

16. Eklund S (2010). Trends in dental treatment, 1992 to 2007. *Journal of the American Dental Association 141*(4): 391-399.

17. Eriksen HM (1998). Has caries merely been postponed? *Acta Odontologica Scandinavia 56*(3): 173-175.

18. Ettinger R (1999). Epidemiology of dental caries. A broad review. *Dental Clinics of North America 43*(4): 679-694.

19. Featherstone JD, Adair SM, Anderson MH, Berkowitz RJ, Bird WF, Crall JJ, Besten PK, Donly KJ, Glassman P, Milgrom P, Roth JR, Snow R, Stewart RE (2003). Caries management by risk assessment: consensus statement, April 2002. *Journal of the California Dental Association 3*1(3): 257-269.

20. Fletcher RH, Fletcher SW, Wagner EH (1988). Clinical Epidemiology; The Essentials (2nd ed.) Baltimore, MD; Williams & Wilkins, pp. 42-61.

21. Graves R, Abernathy J, Disney J, Stamm J, Bohannan H (1991). University of North Carolina caries risk assessment study III. Multiple factors in caries prevalence. *Journal of Public Health Dentistry 51*(3): 134-143.

22. Grindejford M, Dahllof G, Nilsson B, Modeer T (1995). Prediction of dental caries development in 1-year-old children. *Caries Research 29*(5):343-348.

23. Gustaffson BE, Quensel CE, Lanke LS, Lundquist C, Grahnen H, Bonow BE, Krasse B (1954). The Vipeholm dental caries study: the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. *Acta Odontologica Scandinavica 11*: 232–264.

24. Harris R (1963). Biology of the children of Hopewood House, Bowral, Australia. IV. Observations on dental caries experience extending over five years (1957–1961) 1963. *Journal of Dental Research 42*: 1387–1398.

25. Hausen H, Dental Caries The disease and its clinical management. ISBN 1-4051-0718-9. Library of Congress.

26. Hopcraft M, Morgan MV (2003). Dental caries experience in a young adult military population. *Australian Dental Journal 48*(2): 125-129.

27. Kaste LM, Selwitz RH, Oldakowski RJ, Brunelle JA, Winn Dm, Brown LJ (1996). Coronal caries in the primary and permanent dentition of children and adolescents 1-17 years of age: United States, 1988-1991. *Journal of Dental Research 75*(Spec Iss): 631-641.

28. Kennedy ET, Ohls J, Carlson S, Fleming K (1995). The Healthy Eating Index: design and application. *Journal of the American Dietetic Association 95*(10): 1103-1108.

29. Krasse B (2001). The Vipeholm dental caries study: Recollections and reflections 50 years later. *Journal of Dental Research 80*(9): 1785-1788.

30. Larmas M (1992). Saliva and dental caries: diagnostic tests for normal dental practice. *International Dental Journal 42*(4): 199-208.

31. Leiendecker TM, Martin GC, Moss DL, Mongeau SW, Chaffin JG, Dela Cruz GG (2009). DoD Recruit Oral Health Survey. Tri-Service Center for Oral Health Studies. Uniformed Services University of Health Sciences.

32. Leverett DH, Featherstone JD, Proskin HM, Adair SM, Eisenberg AD, Mundorff-Shrestha SA, Shields CP, Shaffer CL, Billings RJ (1993). Caries risk assessment by a cross-sectional discrimination model. *Journal of Dental Research 72* (2): 529-537.

33. Leverett DH, Proskin HM, Featherstone JD, Adair SM, Eisenberg AD, Mundorff-Shrestha SA, Shields CP, Shaffer CL, Billings RJ (1993). Caries risk assessment in a longitudinal discrimination study. *Journal of Dental Research 72*(2): 538-543.

34. Mejare I, Kallestal C, Stenlund H (1999). Incidence and progression of approximal caries from 11 to 22 years of age in Sweden: A prospective radiographic study. *Caries Research 33*(2): 93-100.

35. Mejare I, Stenlund H, Zelezny-Holmlund C (2004). Caries incidence and lesion progression from adolescence to young adulthood: A prospective 15-year cohort study in Sweden. *Caries Research 38*(2): 130-141.

36. Newbrun E, Leverett D (1990). Risk assessment dental caries working group summary statement. In Bader JD, editor. Risk assessment in dentistry: Proceedings

of a conference. Chapel Hill: University of North Carolina School of Dentistry Department of Dental Ecology; pp. 304-305.

37. Newbrun E (1989). Substrate: diet and caries, In Cariology, 3rd Ed., Hanover Park, IL; Quintessence Publishing Co., pp. 99-134.

38. Nunn ME, Braunstein NS, Krall Kaye EA, Dietrich T, Garcia RI, Henshaw MM (2009). Healthy eating index is a predictor of early childhood caries. *Journal of Dental Research 88*(4): 361-366.

39. Ogaard B, Rösler M (1991). Incidence and prediction of filled teeth from 12 to 18 years of age in a district of Norway. *Scandinavian Journal of Dental Research 99*(2): 106-112.

40. Petersson GH, Bratthall D (1996). The caries decline: a review of reviews. *European Journal of Oral Science 104*(4 (Part 2)): 436-443.

41. Powell LV (1998a). Caries prediction: a review of the literature. *Community Dentistry and Oral Epidemiology 26*(6): 361-371.

42. Powell L V (1998b). Caries risk assessment: relevance to the practitioner. *Journal of the American Dental Association 129*(3): 349-353.

43. Roberts-Thomson K, Stewart JF (2008). Risk indicators of caries experience among young adults. *Australian Dental Journal 53*(2): 122-127.

44. Rugg-Gunn AJ, Hackett AF, Appleton DR, Jenkins G, Eastoe JE (1984). Relationship between dietary habits and caries increment assessed over two years in 405 English adolescent school children. *Archives of Oral Biology 29*(12): 983-992.

45. Sheiham A, Sabbah W (2010). Using universal patterns of caries for planning and evaluating dental care. *Caries Research 44*(2):141-150.

46. Sohn W, Burt BA, Sowers MR (2006). Carbonated soft drinks and dental caries in the primary dentition. *Journal of Dental Research 85*(3): 262-266.

47. Snyder ML, Laboratory methods in the clinical evaluation of caries activity (1951). *Journal of the American Dental Association 42*(4): 400-413.

48. Stamm J, Disney J, Graves R, Bohannan H, Abernathy J (1988). The University of North Carolina caries risk assessment study I: rationale and content. *Journal of Public Health Dentistry 48*(4): 225-232.

49. Stamm J, Disney R, Beck, Weintraub J, Stewart S (1993). The University of North Carolina caries risk assessment study: final results and some alternative modeling

approaches. In Bowen WH, Tabak LA (eds.). Cariology for the nineties. Rochester, NY: University of Rochester Press, pp. 209-234.

50. Steiner M, Helfenstein U, Marthaler TM (1992). Dental predictors of high caries increment in children. *Journal of Dental Research 71*(12): 1926-1933.

51. Stephan RM (1940). Changes in hydrogen ion concentration on tooth surfaces and in carious lesions. *Journal of the American Dental Association 27*: 718-723.

52. U.S. Department of Commerce, National Technical Information Service, Division of Health Examination Statistics (1979). National Health and Nutrition Examination Survey (NHANES I) 1971-1974. Dental Data Tape Catalog Number 4235. Hyattsville, Md.: U.S. Department of Commerce.

53. U.S. Department of Commerce Economics and Statistics Administration (2004). U.S. Census Bureau report on educational attainment in the United States, 2003. Annual Social and Economic Supplement.

54. U.S. Department of Health and Human Services and National Center for Health Statistics (1996). Third National Health and Nutrition Examination Survey, 1988-1994. NHANES III Examination Data File (CD-ROM). Hyattsville, Md.: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. Public use data file documentation 76,200.

55. U.S. Public Health Service, National Institute of Dental Research (1980). The prevalence of dental caries in United States children, 1979-1980. Washington, DC: Government Printing Office. NIH Publication No. 82-2245.

56. US Public Health Service, National Institute of Dental Research (1981). The prevalence of dental caries in United States children, 1979-1980.: the national dental caries prevalence survey. NIH Publication No. 82-2245. Washington, DC: US Government Printing Office.

57. U.S. Public Health Service, National Institute of Dental Research (1987). Oral health of United States adults: national findings. Washington, DC: Government Printing Office. NIH Publication No. 87-2868.

58. U.S. Public Health Service, National Institute of Dental Research (1989a). Oral health of United States children, Washington, DC: Government Printing Office. NIH Publication No. 89-2247.

59. US Public Health Service, National Institute of Dental Research (1989b). Oral health of United States children: the National Survey of Dental Caries in U.S. School Children, 1986-1987: national and regional findings. NIH Publication No. 89-2247. Washington, DC: US Government Printing Office.